1. **Industrial Grade (High Tenacity) Fibers**

   Fibers are the foundation for all twine, cables, cordage, rope, and netting products. In the past ten years, there have been many new developments in fibers. It is important; therefore, that engineers and users understand and appreciate the "building blocks" of any strength member product.

   Historically, cordage, ropes and twines were made from natural (vegetable) fibers. While these are still important for some applications, virtually all modern cordage products are based on synthetic fibers.

   For the purpose of this document industrial grade fibers used in quality cordage and rope are synthetic fibers with a tenacity up to 15 grams per denier (gpd). High performance fibers used in quality cordage and rope are synthetic fibers with a tenacity above 15 grams per denier (gpd).

   Many synthetic fibers can have a pigment added during the manufacturing process resulting in permanent color. A variety of colors are available.

1.1 **Polyamide (Nylon)**

   The first man-made fiber used in cordage was nylon. It is a manufactured fiber composed of linear macromolecules having in the chain recurring amide linkages, at least 85% of which are joined to aliphatic or cycloaliphatic units. Two types of nylon are commonly used in rope making. Nylon 6 is made from amino caprolactam. Nylon 6,6 is made from hexamethylene diamine and adipic acid. The principal property difference is melt point.

   The proper chemical name for nylon is polyamide.

   Chemical abbreviation: PA

   Chemical formula:
   
   \[
   \text{[-NH-(CH}_2\text{)}_5\text{-CO- }]_n \text{ (nylon 6), and}
   \]
   
   \[
   \text{[-NH-(CH}_2\text{)}_6\text{-NH-CO(CH}_2\text{)}_4\text{-CO- }]_n \text{ (nylon 6,6).}
   \]

   Fiber tenacity ranges are from 7.5 to over 10.5 gpd.

1.2 **Polyester**

   A manufactured fiber produced from the linear polymer ‘polyethylene terephthalate’.

   Chemical abbreviation: PET (PES is also sometimes used)

   Chemical formula: \([-\text{OC-C}_6\text{H}_4\text{-COO-CH}_2\text{-CH}_2\text{-OH}]_n\) or more simplified \((\text{C}_{10}\text{H}_{8}\text{O}_4)_n\)

   More generally, polyester includes polymers composed of linear macromolecules having in the chain at least 85% by mass of an ester of a diol and terephthalic acid. Such linear polyesters are fiber forming.
Tenacity ratings of industrial polyester fibers range from 7.0 gpd to over 10.0 gpd.

Higher modulus polyesters, such as PEN (Polyethylene naphthalate) are also available.

1.3 **Polyolefins**
A class of polymers in which the fiber-forming substance is any long-chain synthetic polymer composed of at least 85% by weight of ethene (ethylene), propene (propylene), or other olefin units. This class includes Polypropylene and Polyethylene.

1.3.1 **Polypropylene**
A manufactured fiber formed by melt spinning and drawing polymers or copolymers of propylene, an aliphatic saturated hydrocarbon linear macromolecule where one carbon atom in two carries a methyl side chain in an isostatic disposition and without further substitution.
Chemical abbreviation: PP
Chemical formula: -(CH₂-CH(CH₃))-

1.3.2 **Polyethylene**
A manufactured fiber formed of polymers of ethylene, synthetic linear macromolecules of unsubstituted aliphatic saturated hydrocarbon.
Chemical abbreviation: PE
Chemical formula: -(CH₂-CH₂)-

1.3.3 **Copolymer Fibers**
Copolymer is the industry term for the melt combination of olefin polymer(s) (polypropylene/polyethylene) together or with other polymer(s) such as polyester. In most cases, copolymer combinations are based on proprietary formulas.

1.4 **Fluoropolymers**
A class of fluorocarbon-based polymers with very strong carbon-fluorine bonds which are inherently chemically stable.

1.4.1 **Expanded Polytetrafluoroethylene (ePTFE)**
A manufactured fiber formed of long polymer chains of PTFE stretched into nodes and fibrils.
Chemical formula: -(CₙF₂ₙ)-

2. **Combination, Duplex, or Blended Fibers**
Cordage and rope can be made with the properties of more than one fiber by combining them in a single construction. In stranded and single-braided ropes, this is usually done by the combining of yarns or filaments of different fibers in the making of strands. In double-braided ropes this can also be done by using one type of fiber in the core and another in the cover, by utilizing differences in the fiber characteristics through the braid design.
3. Natural Fibers
   NOTE: Ropes made from natural fibers can lose significant strength under normal storage conditions. For this reason, natural fiber ropes should NOT be used in applications where life and limb is at risk.

   Natural vegetable fibers are classified as hard fibers or soft fibers. Generally speaking, hard fibers form the structural system of the leaf or plant, examples are: sisal or Manila. Soft fibers are found in the bast layer of the plant stem, examples are: hemp, jute, flax and cotton.

3.1 Abaca (manila): Abaca is obtained from the tropical plant Musa Testilis, a member of the banana plant family. It is commonly known as Manila hemp, which is a misnomer since the hemp plant belongs to the soft fiber group. Abaca is the strongest of the natural fibers. The majority of manila is grown in the Philippines.

3.2 Sisal and henequen: Sisal (Agave sisalana) and henequen (A. fourcroydes) are hard fibers. Henequen is sometimes called Mexican or Cuban sisal. Various sisals are identified by country of origin: Brazil, Haiti, Kenya, Tanzania, and Indonesia being the major producers.

3.3 Others: Jute is a soft fiber and comes from two closely related plants: Corchorus capsularia and C. olitorius. Hemp is a soft fiber and comes from the Cannabis sativa plant. Cotton is a natural fiber widely used in the textile industry, including some cordage and smaller diameter ropes. Cotton is often blended with synthetic staple fibers for additional strength and improved abrasion resistance.

4. High-Performance High-Modulus Fibers
   These fibers have a tenacity greater than 15.0 grams/denier (gpd). The first of these was paraaramid (1970’s) followed by High Modulus PolyEthylene (HMPE, 1980’s) and liquid crystal polyester (LCP, 1990’s).

4.1 Para-aramid fibers. A manufactured high-modulus fiber in which the fiber-forming substance is a long chain synthetic aromatic polyamide in which at least 85% of the amide linkages are attached directly to two aromatic rings.

4.2 High Modulus Polyethylene (HMPE). A polyolefin fiber produced by gel spinning or solid-state extrusion of an Ultra High Molecular Weight Polyethylene (UHMWPE) feedstock to produce extremely high tenacity. Also called Extended-Chain Polyethylene (ECPE) or High-Performance Polyethylene (HPPE).

4.3 Liquid Crystal Polyester (LCP). A thermotropic liquid crystal aromatic polyester fiber produced by melt spinning. It is a high-performance multifilament yarn with high tenacity and modulus. Also known as polyester-arylate or polyarylate.

4.4 Poly-Para-Phenylene Bisoxazole (PBO). PBO is polymerized from diaminoresorcinal dichloride and terephthalic acid in polyphosphoric acid.
Table 1: Cordage Institute Industrial Fibers Chart
(Industrial fibers are defined as having an average breaking tenacity between 5.0 and 15.0 grams/denier)

<table>
<thead>
<tr>
<th>Physical Properties (1)</th>
<th>Long-term / Environmental Properties (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Resistance to Abrasion, Creep, and Sunlight Exposure</td>
</tr>
<tr>
<td>Generic Fiber Description</td>
<td>Density [g/cm³]</td>
</tr>
<tr>
<td>Polyamide (nylon) PA 6 or PA6,6</td>
<td>1.14</td>
</tr>
<tr>
<td>Polyethylene terephthalate (polyester) PET or PES</td>
<td>1.33-1.38</td>
</tr>
<tr>
<td>Polyethylene naphthalate PEN</td>
<td>1.40</td>
</tr>
<tr>
<td>Polypropylene PP</td>
<td>0.91</td>
</tr>
<tr>
<td>High Modulus Polypropylene HMPP</td>
<td>0.84</td>
</tr>
<tr>
<td>Expanded Polytetrafluoroethylene ePTFE</td>
<td>0.95-0.97</td>
</tr>
<tr>
<td>Copolymer PP/PE</td>
<td>0.91-0.93</td>
</tr>
<tr>
<td>Copolymer PP/PES</td>
<td>0.98-1.15</td>
</tr>
<tr>
<td>Cotton (see Note 3) Natural cellulose fiber</td>
<td>1.54</td>
</tr>
<tr>
<td>Natural fiber (see Note 3) Abaca, agave, sisal</td>
<td>1.32</td>
</tr>
</tbody>
</table>

This information is provided by the fiber manufacturers and is not intended as a Cordage Institute endorsement. Fiber selection should involve discussions with both fiber and cordage manufacturers.

**Physical Property Definitions:**
- **Breaking Tenacity:** break load in grams force per denier weight.
- **Elongation at Break:** change in yarn length at break, expressed as percent of initial gage length.
- **Moisture regain:** tested at standard conditions of 72°F at 65% relative humidity.

**Long-term / Environmental Property Definitions:**
- Long term properties are dependent on end use and environment. Always consult the rope manufacturer before choosing a rope for extended service.

**Notes:**
- Note 1: Resistance to abrasion is relative to other industrial fibers in this chart.
- Note 2: LDPE is Low Density Polyethylene
- Note 3: Natural fibers are subject to degradation by fungal/bacterial attack during storage. Ropes made from natural fibers should not be used in applications where life and limb are at risk.

Special overlay finishes are available to enhance the strength and abrasion resistance. See page 6 for fiber producers contact information.
## Table 2: Cordage Institute High Tenacity Fiber Chart
(High Tenacity for purposes of this chart is any fiber with a tenacity greater than 15.0 grams/denier)

<table>
<thead>
<tr>
<th>Fiber Description</th>
<th>Physical Properties</th>
<th>Long-Term / Environmental Properties (see footnotes)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fiber Description</strong></td>
<td><strong>Physical Properties</strong></td>
<td><strong>Long-Term / Environmental Properties (see footnotes)</strong></td>
</tr>
<tr>
<td>LCP Polyester-Polyarylate</td>
<td>Vectran™</td>
<td>Light Gold</td>
</tr>
<tr>
<td>Para-Aramid</td>
<td>Twaron®</td>
<td>Yellow</td>
</tr>
<tr>
<td>Aramid Copolymer</td>
<td>Technora®</td>
<td>Gold</td>
</tr>
<tr>
<td>HMPE (1) (gel spun)</td>
<td>Deyontron-text®, Dynex®</td>
<td>White</td>
</tr>
<tr>
<td>HMPE (solid state)</td>
<td>Endumax®</td>
<td>White</td>
</tr>
<tr>
<td>PBO (2)</td>
<td>ZYLON®</td>
<td>Gold</td>
</tr>
</tbody>
</table>

### Footnotes:
- Creep - A gradual change in length under the effects of an applied static tensile load, which is influenced by testing temperature and applied load.
- Abrasion – Reduction in strength caused by interaction with surrounding fibers or surfaces. (Overlay finishes and lubricants can enhance abrasion resistance under both wet and dry conditions.)
- Sunlight – Synthetic fibers are susceptible to degradation on direct exposure to sunlight. Degradation of fibers within a rope can vary depending on rope construction, coatings and other factors.
- Chemical Exposure – Fibers may be chemically degraded by exposure to specific agents. Data on chemical resistance should be obtained from the fiber companies, as listed on page 7, and the rope manufacturers.

### Long-Term Properties:
These long-term properties are dependent on end use and environment. Always consult the rope manufacturer before choosing a rope for extended service. Repackers should be consulted if ropes are to be used in extreme heat or cold. Creep – A gradual change in length under the effects of an applied static tensile load, which is influenced by testing temperature and applied load. Abrasion – Reduction in strength caused by interaction with surrounding fibers or surfaces. (Overlay finishes and lubricants can enhance abrasion resistance under both wet and dry conditions.)

### High Tenacity Fiber Chart:
This information is provided by the fiber manufacturers and is not intended as a Cordage Institute endorsement. Fiber selection should involve discussions with both fiber and cordage manufacturers.
**Cordage Institute Member Fiber Producers**

**Avient**  
Bill Fronzaglia  
5750 Martin Luther King Jr. Highway  
Greenville, North Carolina 27834-8628  
Tel: 704-862-5000  
E-mail: bill.fronzaglia@dsm.com  
Website: www.dyneema.com

**Products:**  
HMPE Polyethylene. Ten grades (Dyneema® SK38, SK60, SK62, SK65, SK71, SK75, SK78, SK99, DM20, SK78XBO & DM20XBO).

**Brand Name:**  
Dyneema®, Trosar™: Property of Avient

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**Beijing Tongyizhong Specialty Fiber Technology & Development Co., Ltd**  
Nina Zhang  
No.16 Zhonghe Street, Economic & Technological Development Area  
Beijing, China  
Tel: +86 (10) 56710302  
Fax: +86 (10) 56710309  
E-mail: nina@bjtyz.com, bjtyz@bjtyz.com  
Website: http://en.bjtyz.com

**Products:**  
Ultra-High Molecular Weight Polyethylene fiber (UHMWPE)  
Available in wide range of customized deniers  
Colored UHMWPE fiber, like Neon Green, Lemon Yellow, Flame Red, Black, Blue, etc.

**Brand Name:**  
Doyentrontex®

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**BeyondFibre**  
Jehan van Dijk  
Postbus 11589  
1001 GN Amsterdam, Netherlands  
Tel: +31654628827  
Email: jehan@beyondfibre.com, edward@beyondfibre.com

**Products:**  
HMPE Polyethylene (SW39, SW65, SW75, SW85, SW90, SW100, SW200).

**Brand Name:**  
BeyondFibre
Brilen Tech, S. A.
Laura Alcober
Paseo de la Independencia 21
3rd Floor
Zaragoza, 50001 Spain
Tel: +34 974 316 065
Email: lalcober@samca.com

Products:
Deep Sea Treatment (DST Marino®), Minimum elongation (FHS), High Tenacity High Modulus (GLE),
High Tenacity and Shrinkage (GLS), High Shrinkage Fiber (HSF), High Tenacity Medium Shrinkage (NLS),
Retention Systems (SBX), Very Low Shrinkage (VLS), Ultra Low shrinkage (VLR), Top Breaking Force (TBF) Polyester Fibers.
Available in various colors, deniers, and packaging.
Anti-Wick, Flame Retardant and Food contact available.
GRS Recycled yarn range.

Brand Name:
BRILEN DST marino ®, BRILEN® FHS, BRILEN® GLE, BRILEN® GLS, BRILEN® HSF, BRILEN® NLS, BRILEN® SBX, BRILEN® VLS, BRILEN® VLR, BRILEN® TBF

FibrXL
Benno ter Horst
4590 Vawter Avenue
Richmond, VA 23222
Tel: 804 329 4383
Fax: 804-977 5089
Email: Benno.terhorst@fibrxl.com
Website: www.fibrxl.com

Products:
Polyester HT Yarn: Regular Shrink, Low Shrink, dope dyed colors, Marine finish, HMLS
Polyamide 6 HT Yarn: Regular Shrink, low Shrink, dope dyed colors
Polyamide 66 HT Yarn: Regular Shrink, low Shrink
UHMWPE: natural, dope dyed colors, anti-stat, coated
Aramid: Para Aramid, Meta Aramid

Brand Names:
Prisma® : Enhanced coating technology for High Performance Fibers
Oblix™ : Impregnated UHMWPE (DSM Dyneema)
Atlas: UHMWPE Yarn
Hercules: Para Aramid Yarn
Hailide America, Inc.
Stuart Smith
1776 Peachtree St. NW
710S
Atlanta, GA 30309
Tel: (404) 974-3232
Fax: (404) 974-3233
E-mail: stuart.smith@hailideamerica.com
Website: www.hailideamerica.com

Products:

Brand Name:
Halead®

Honeywell Advanced Fibers & Composites
Brent Gerdes
15801 Woods Edge Road
Colonial Heights, VA 23824-0031
Tel: 302-501-2136
Alternate Tel: 804-930-7567
E-mail: brent.gerdes@honeywell.com
Website: www.spectrafiber.com

Products:

Brand Name:
Spectra®

Kuraray America, Inc.
Forrest Sloan
460-E Greenway Industrial Drive
Fort Mill, SC 29708
Main: 803-396-7350
Direct: 804-654-0010
E-mail: forrest.sloan@kuraray.com
Website: www.kuraray.us.com

Products:
High tenacity liquid crystal polyester (LCP) fiber

Brand Name:
Vectran® HT, UM
Nexis Fibers
Barbara Danak
Market Manager, North and South America
Nexis Fibers
Tel: 1-770-331-5380
Cell: 1-423-802-6161
Email: Barbara.danak@nexis-fibers.com
Website: www.nexisfibers.com
Twitter: @nexisfibers

Products:
High and Super High Multifilament Fiber in Polyamide 6 & 6,6
Spun Dyed High Tenacity Multifilament Fiber in Polyamide 6

Teijin Aramid USA
Amy Jenkins
801 F Blacklawn Rd
Conyers GA 30012
Tel: 800-451-6586
Email: amy.jenkins@teijinaramid.com
Website: www.teijinaramid.com

Products:
Low, intermediate, and high modulus aramid fibers
HMPE material

Brand Names:
Twaron® and Technora®
Endumax®

TOYOBO Co., LTD
2-2-8 Dojimahama, Kita-ku, Osaka 530-8230, Japan
Tel: +81-6-6348-3445
Fax: +81-6-6348-3450
Email: go_matsuoka@toyobo.jp
Website: http://www.toyobo-global.com/

Products:
- High Modulus Polyethylene (HMPE)
  Several grades (SK60, SK777, SF600, SF700 and SF800) having different tenacity and deniers are available.

- Poly (p-phenylene-2, 6-benzobisoxazole) (PBO)
  Both regular (AS) and High modulus (HM) grade are available. Range of deniers is between 237 to 3270 dtex.

Brand Names:
IZANAS® (HMPE) and ZYLON® (PBO)
**TP Industrial Yarns**  
Contact Friso Heeren  
8530 Steele Creek Place Drive, Suite A  
Charlotte, NC 28273  
United States of America  
Phone +1-734-548-8046  
Email Friso.Heeren@tp-industrial.com  
Website https://www.tp-industrial.com/  

**Products:**  
TITAN HMPE Polyethylene: Three grades (Type 850, 860 & 850 Spun Dyed Colors)  
Aramid: Para Aramid yarns four grades (type 951 (also in black), 961,971,971), Meta Aramid yarns deniers available 200D, 1200D, 1600D  
High Tenacity (HT), Polyester: Available in natural & various colors, deniers, and packaging. High Tenacity (HT), Super High Tenacity (SHT), Marine Finish.  
Polyamide 6.6: Available in natural & black, deniers, and packaging. High Tenacity (HT), Super High Tenacity (SHT), Marine Finish.  

**Brand Names:**  
TITAN  

⚠️ **WARNING**  
The use of rope and cordage products has inherent safety risks which are subject to highly variable conditions and which may change over time. Compliance with standards and guidelines of the Cordage Institute does not guarantee safe use under all circumstances, and the Institute disclaims any responsibility for accidents which may occur. If the user has any questions or uncertainties about the proper use of rope or cordage or about safe practices, consult a professional engineer or other qualified individual.